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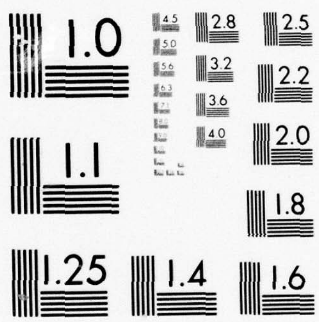
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CONTROL DATA CORPORATION

ASW MISSION EFFECTIVENESS COMPUTER PROGRAM DESCRIPTION

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ASW MISSION EFFECTIVENESS COMPUTER PROGRAM DESCRIPTION

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ABSTRACT

This report is a description of the pilot version of the ASW Mission Effectiveness computer program. Sections I and II discuss the purpose of the program and the simulation model for the reader without a computer programming background. Section III is a description of the program organization for a reader with such a background. This is the final report covering activities performed under WP11-7. The interim report (TRG Report No. 023-TM-66-18) gave a cursory description of this program at a late stage in the keypunching phase of the various decks which constitute this program. Many revisions and corrections have been made since then. This final report describes the program at an early stage of the debugging and testing phase (WP11-8). The initial results from this program will be described in the next report, the first report covering activities performed under WP11-8.

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SECTION I

INTRODUCTION

The ASW mission effectiveness computer program (MEP) simulates a complex ASW action involving ships, submarines, aircraft, and their respective sensors and weapons. Its purpose is to produce a narrative of events which will show the effect of sonar system performance on the accomplishment of a mission. This performance, as well as the performances of the other sensors, platforms, and weapons, are either input to the computer program or stored within the program in the form of tables.

MEP is designed to simulate tactical situations involving 25 to 30 units, e.g., a dozen or so convoy ships, a screen of 5 or 6 destroyers, several aircraft, and submarine adversaries. The number, type, and initial disposition of these units is set up by input. The tactical doctrine which controls the decisions of the commanding officers during the course of the action is input in a language designed for this purpose. Decisions are made on the basis of information available to commanding officers from their sensors. The decisions made cause certain actions to take place, e.g., a ship maintains or changes course, sends or receives a message, continues or alters the sonar operating procedure, etc. Actions produce new information for the next set of decisions. Thus, MEP simulates a closed-loop information-feedback system where the information available (because of sensor performance) controls the decisions that affect the information available (because of the actions caused by the decisions).

MEP is organized around the functions which are relevant to the purpose of determining the effect of sonar performance on the accomplishment of a mission. The selection of the functions to include in the pilot version of MEP

represent an a priori judgment of the factors relevant to its purpose. For example, the ship's galley is not included in MEP because the crew's diet is not considered relevant to the ASW effectiveness of the ship. Inter-ship communication is included because it is clearly relevant to the effectiveness of the defensive screen. Each functional area is simulated in MEP by a separate deck, e.g., the tactical decision function by the CO deck, the steering of a unit by the PI deck, etc.

Each deck carries out its function for each unit currently active at each time step during the course of the action. Thus, the CO deck successively handles the decision making of the destroyer commanding officer, the aircraft pilot, etc. On some units, each function would be performed by different men or groups of men and their associated equipment, while on other units several functions would be performed by one man. For example, on an aircraft the functions simulated by the CO and PI decks would be performed by the pilot.

The success of MEP depends critically on the functions chosen to be simulated. It has been carefully organized into program modules or decks so that if the testing phase shows that a relevant function has been omitted, a deck can be added without serious consequences to the existing decks. The current version of MEP will be designated the pilot version until tests demonstrate the validity of the simulation.

The simulation is controlled by an executive program (the EX deck) which advances time from T.MIN to T.MAX in increments of ΔT hereafter called D.T (these parameters are input and remain constant during a run). During the course of the action, the information generated during the previous time interval of length D.T forms the basis for the decisions at time T which determine the actions during the following time interval. This "time-step" organization of the simulation is a consequence of the fact that tactical doctrine has not been written into the program. It is not possible to advance the simulation on an "event-store" basis because the program cannot

predict what the next event will be.

Tactical doctrine is input to the program in the form of conditional statements (see Appendix A). These state that if a unit is in a particular operational phase and the specified information is reported by the sensors, then certain actions will be initiated. At each step of D.T, the program must discover which information specification is satisfied in order to initiate a course of action.

A consequence of this time-step organization is that actions can only be initiated at values of time that are multiples of D.T. For example, if input sets D.T to a value of 30 seconds, then it is being assumed that the exact moment an action is initiated is significant only within plus or minus 15 seconds (an assumption which would probably be true in a scenario involving conventional submarines, but false if nuclear boats were involved). The value of D.T assigned determines the cost of a run so that it is important to establish the feasible range of values for it versus the types of scenarios of interest.

SECTION II

SIMULATION MODEL

The pilot version of MEP simulates nine functional areas. Each of these areas is simulated by a separate deck:

Deck	Function
AS	A/S Officer, A/D equipment and operator
CE	CIC Evaluation Officer, communication, report evaluation
CO	Commanding Officer, tactical decisions and doctrine
FO	Firing Petty Officer, weapon processing
GL	Communication Region: CI.NET, communication between decks. Status Region: time parameters, environmental data
LO	Lookout, visual reports
PI	Pilot, steering and propulsion
SO	Sonar set and operator, sonar reports
SU	Sonar Supervisor, sonar operating procedures

Each of these decks depends on the other decks as shown in Figure 2-1. Communication between decks is accomplished by lists of information in the communication region of the GL deck (see Appendix C). These lists are shown as arrows in Figure 2-1. They have names of the form XX..YY where deck XX produces the information in the list for use by deck YY, e.g., CE..CO is a list of information from the CE deck to the CO deck. CI.NET is used for inter-ship communication. The nine decks listed above have counterparts in the real world. The following six decks do not, but perform various data processing and control functions:

Deck	Function
DB	Debugging routines
EX	Executive control program

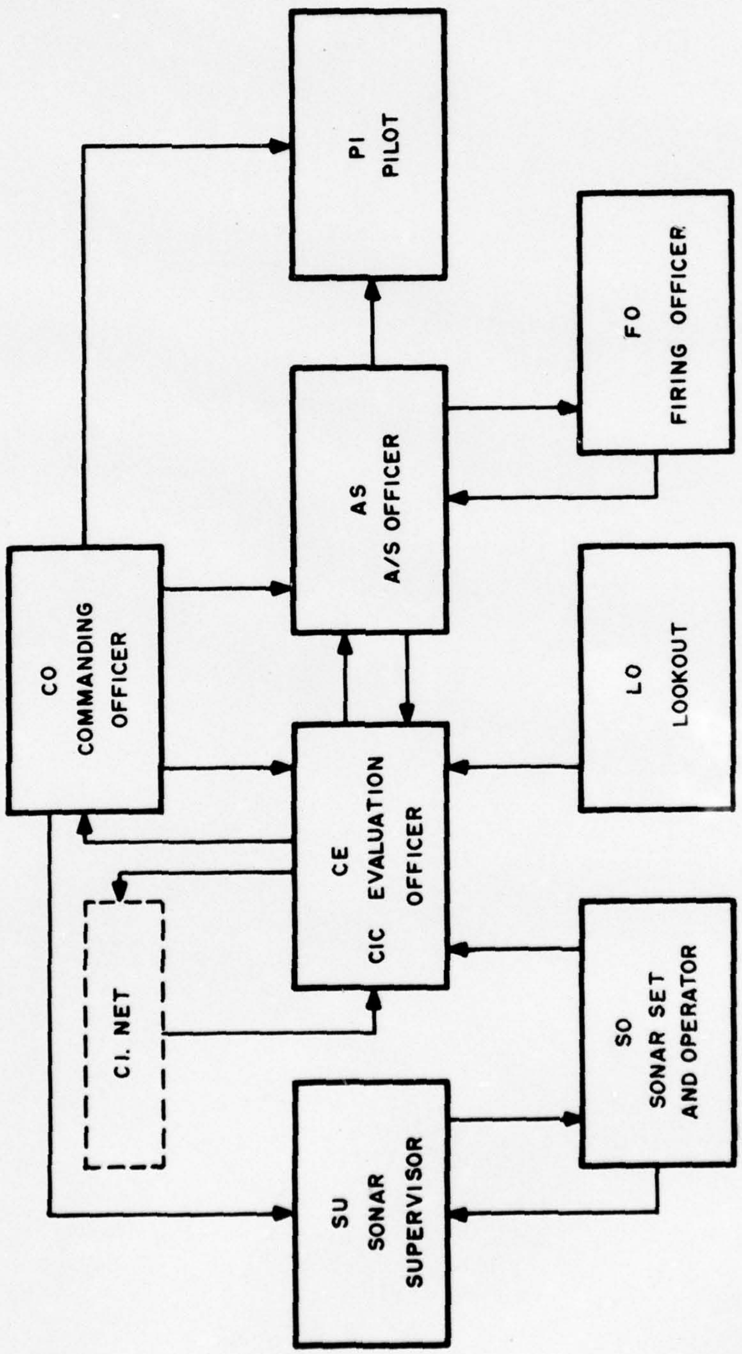


FIGURE 2-1. "MEP" INFORMATION FLOW

Deck	Function (contd)
FN	Mathematical function library and list processing routines
IN	Input data processing program
IO	Input-output subroutines
PP	Post-processing program

In the following section (Section III) there are deck descriptions which are meant for the reader with a computer programming background. In this section, some aspects of the MEP model are discussed in non-programming language. However, it must be stressed that this results in some circumlocution and loss of precision. In the final analysis, the MEP model is the program listing for GL and eight decks shown in Figure 2-1. This listing is approximately 400 pages long so that it is not practical to include it in this report.

A. INTER-SHIP COMMUNICATION

Communication between units is simulated in the CE and GL decks. The processing is done by the CE deck, and the messages are in lists which make up CI.NET in the GL deck. When a CO decides to send a message, it is given to the CE deck. For a given time interval, W.LIST will have all the messages that are waiting for transmission to other units. Before the CO deck processes all units currently active for the next time interval, the CE deck processes the lists which make up CI.NET.

CI.NET contains the acknowledged messages (A.LIST), the messages being transmitted (C.LIST), and the messages waiting for transmission (W.LIST). The CE deck processes CI.NET in three steps. First, it erases A.LIST (messages in this list at this time will have been delivered during the previous time interval). Next, the CE deck examines the messages in C.LIST. Each message requires a length of time to be transmitted which is a function of its length. If a message has been in C.LIST for the required length of time, it is taken out of C.LIST and put in A.LIST so that it will be available during the next time interval. Finally, the CE deck fills

C.LIST with messages from the W.LIST. The number of messages which can be in C.LIST simultaneously is controlled by input. A message in W.LIST must be transmitted, i.e., put into C.LIST within a specified time which is a function of its priority or it is erased.

This model allows various communication phenomena to be simulated. If the number of transmission channels in C.LIST is set to zero, no inter-ship communication can take place, and each CO will have to rely on doctrine and his own sensors. If the number of transmission channels is small, e.g., one or two, a communication jam could occur if the prosecution of an attack depended on a team effort of several units.

B. <u>A COURSE MANEUVER</u>

Course maneuvers result from a CO's tactical decision. For the sake of concreteness, assume that a submarine's passive sonar has picked up the noise of heavy screws and the CO decides to head directly for the source of this noise. This is a common initial maneuver for a submarine whose mission is anti-shipping. This course would be held until the submarine obtains enough information to estimate the course of its target. To carry out this maneuver the CO deck constructs a list called CO..PI which gives orders to the PI deck. This list also contains the sonar report on the target toward which the PI deck is to steer the submarine.

The function of the PI deck is to advance a unit along its track. In this example it would advance the submarine and turn towards the true bearing given in the report which is part of the CO..PI list. Let this desired true bearing be 030 and assume that the current heading of the submarine is 150, then the PI deck would turn the submarine to port. However, D.T (the basic time-step for the situation) may be too small for the submarine to accomplish a 120-degree turn to port within one time interval. Maximum turn rates for each type of unit are controlled by a table in the PI deck. If

this table limits the submarine to a 90 degree turn for one time-step, then the PI deck would turn the submarine 90 degrees to port and it would be on a heading of 060. In the position-course-speed data for the submarine, the PI deck would record the current course maneuver and a desired course heading of 030. Assuming that information does not develop which would cause the CO to order a different course maneuver, the PI deck would continue the current maneuver during the next time interval and complete the turn to a heading of 030.

C. INITIATING AN ATTACK

Initiating an attack is a CO's tactical decision which is carried out by the A/S officer. To initiate the attack, the CO constructs a list called CO..AS which gives orders to the AS deck. The functions of the AS deck are to conn the attack and determine time to fire.

The A/S officer gets the latest report on the target from the CE and constructs the AS..PI list, specifying a collision course computed from the data in the last report of the target. An AS..FO list is constructed that orders the firing petty officer to begin weapon preparation.
fire is computed by the A/S officer. This time is based on target range and range rate and the firing range of the weapon. The target data is obtained from the last report on the target, and the weapon data is obtained from a list produced by the FO deck. This list is constructed from tables in the FO deck.

If the time to fire computed by the A/S officer falls within the next time step, the weapon is launched. Otherwise, no weapon is fired and the calculation must be repeated at the end of the next time step.

The model allows various features of an attack situation to be simulated. A weapons store is maintained for each unit that can initiate an attack. This store is reduced every time a weapon is fired, and updated when weapons are returned as, for example, when an attack is called off.

Thus it is possible for a unit to exhaust his supply of weapons. Time to fire is based on target reports and, thus, target report inaccuracies can influence both the initial decision to fire and the success or failure of the weapon launch.

D. PASSIVE SONAR REPORT

The sonar set output produced by the SO deck is a list of "reports" called the SO..CE list. For a sub operating in the passive mode, both noise and echo ranging pings could be part of the sonar set output. A passive sonar "report" which describes the noise picked up from a convoy ship would contain a noise level index, and information about the noise source such as true bearing, bearing drift, and target speed. The noise level vs. range tables are in the SO deck. For each type of sonar set there there are tables for above-layer and below-layer reception. A passive sonar "report" which describes echo ranging ping reception would be similar to a noise report, except that it would have a time associated with it, a code designating long or short scale, and different tables would be used to get the signal level level index.

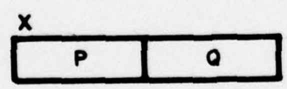
SECTION III

PROGRAM ORGANIZATION

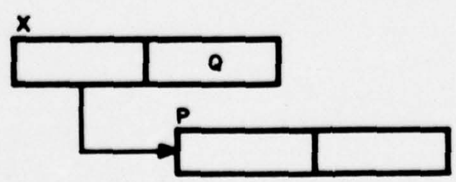
MEP is written in MAP, the assembly language of the IBJOB monitor which runs under IBSYS on the IBm 7094 computer. MEP is divided into 15 decks, 9 of which have counterparts in the real world and are described in Appendix B. A dynamic storage allocation technique is used which is similar to the one used in LISP*.

A. LIST STRUCTURE DIAGRAMS

A list structure diagram consists of rectangular symbols which represent storage cells and arrows. As in LISP, the left half of a symbol represents the address part of a word in storage, and the right half represents the decrement part:

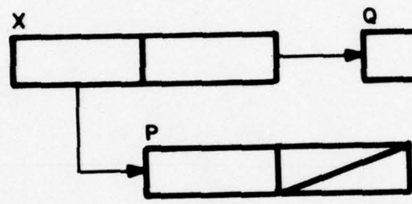


In this example, the address of P is in the address part of the word in symbolic location X, the address of Q in the decrement. An equivalent statement is that the address part of the word in symbolic location X "points" to P, the decrement part "points" to Q. If the word in location P is a continuation of the list structure as shown below:



*McCarthy, Abrahams, Edward, Hart, and Levin, "LISP 1.5 Programmer's Manual", MIP Press, Cambridge, Mass., 1962

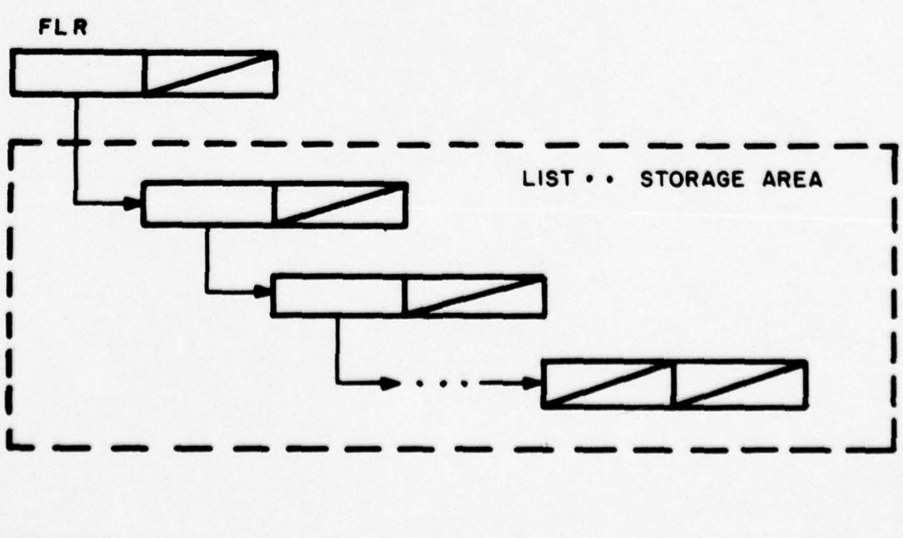
then P would not be written in the symbol for the word in location X, but would be replaced by an arrow drawn to the symbol which represents the list structure word in location P. As in LISP, if the address or decrement part of a word is zero, it is said to point to NIL. In a list structure diagram this is indicated by a diagonal line drawn through that part of the symbol:



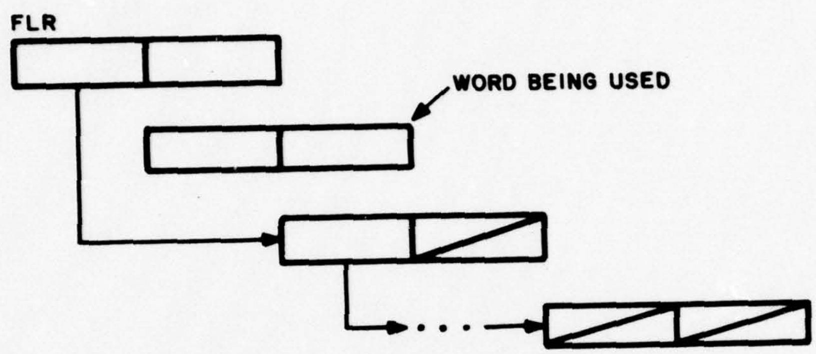
In this example the decrement parts of the words in locations P and Q point to NIL. This indicates that the decrement parts of these words do not lead to further list structure.

B. LIST CONSTRUCTION

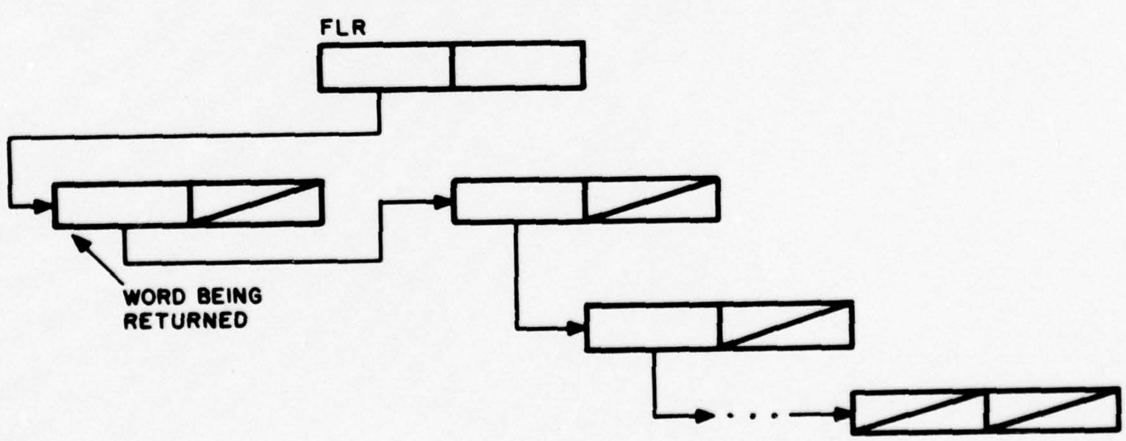
At the start of each run the storage area in the GL deck called LIST.. is linked into one list called the "free storage list" and the address part of the word in location FLR is set to point to the first word in this list:



A routine which requires a word to construct a list obtains this word from the free storage list by using the word to which FLR points, and setting FLR to point to the next word in the free storage list:

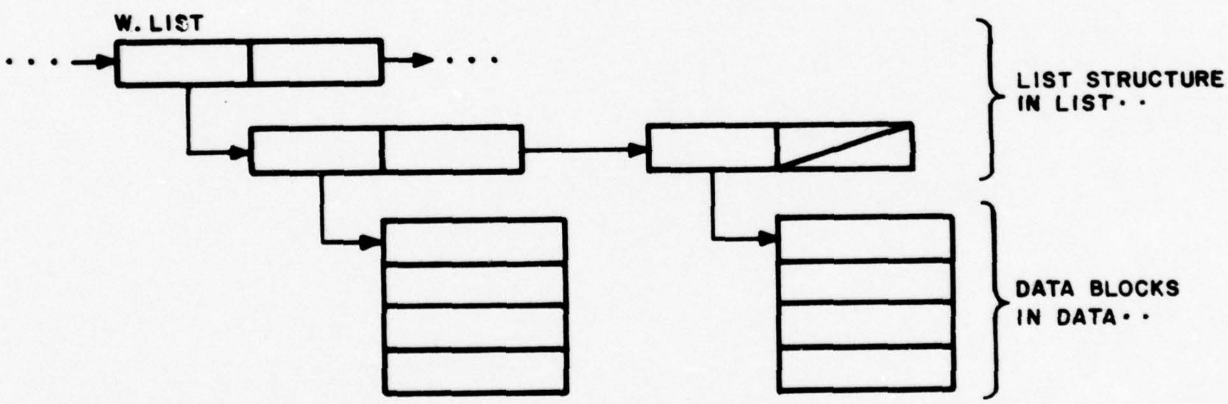


When a list structure word has served its purpose, it is returned to the free storage list by making it point to the same word that FLR currently points to, and then setting FLR to point to the word being returned:

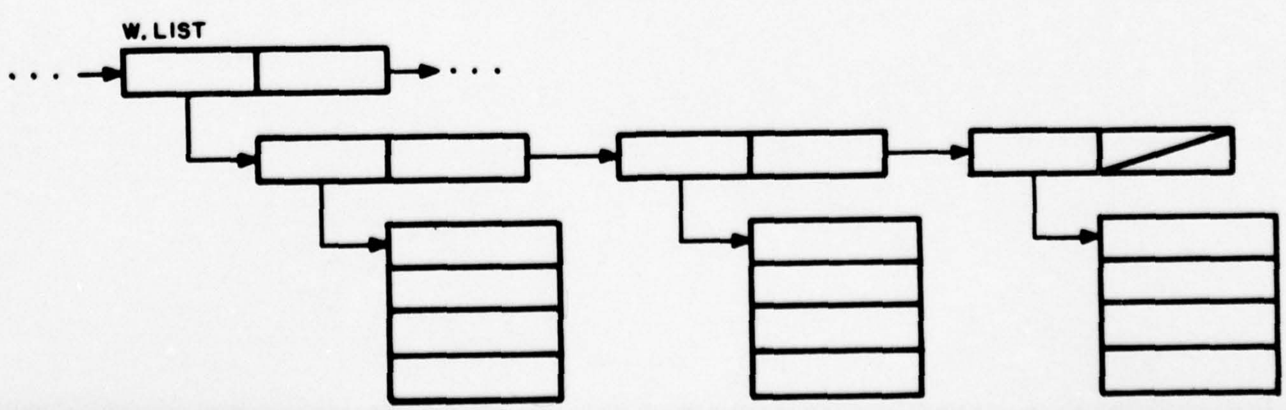


These procedures allow storage for list structure to be allocated dynamically during a run. At the time a routine needs to build up a list structure, it obtains the words for this structure from the free storage list. When the list structure is no longer needed, the words from which it is constructed are returned to the free storage list for use by another routine.

List structure is used to link data blocks which contain the information in a list. A data block is a group of four consecutive words in storage. All data blocks are in a storage area called DATA.. in the GL deck. At the start of a run the first words in each of these blocks are linked together in the same way as the free storage list. The word in symbolic location FBR is set to point to the first block in this list. Data blocks are obtained and returned in the same manner as described above. For example, W.LIST contains the messages waiting for transmission during the next time interval. Assume that two messages are in W.LIST. Then, in diagram form:



Each data block would contain the information associated with one of the messages waiting for transmission. Assume that another CO decides to send a message, then a word is obtained from LIST.. via FLR, a data block is obtained from DATA.. via FDB, and the message is added to W.LIST:



When these messages have served their purpose, the list structure and data blocks to which the address part of W.LIST points are returned to LIST.. and DATA.. so that they may be used by other routines.

C. LIST PROCESSING SUBROUTINES

The decks described in Appendix B process the information in various lists, and either produce other lists or alter the information in existing lists. The FN deck contains subroutines which are used for the creation or modification of lists. The principles on which these subroutines are based have been explained above. Two basic operations occur frequently in locating and processing information in a list: CAR and CDR.

CAR, the contents of the address register, is used in a declarative sense in the deck descriptions in Appendix B. The statement "CAR(X) is the list Y" means that the address part of the word in symbolic location X points to the list structure which is the list Y. CDR has an analogous meaning for the decrement. In the program, CAR and CDR have an imperative force. They are macro instructions which expand as follows:

```
CAR:  PAC   ,7                    CDR:  PDC   ,7
      CAL   0,7                         CAL   0,7
```

If CAR(X) is Y, then the following sequence of instructions will get the first word of the list structure that is Y:

```
      CAL   X
      CAR
```

Thus, if the location of the first word of a list is known, any part of the list can be located with the appropriate sequence of CAR's and CDR's.

D. UNIT DESCRIPTIONS

U.LIST is a list which describes all the units currently active. Information in this list is used by all the decks described in Appendix B. The IN deck constructs U.LIST from the information supplied by the FORCES... section of the input data. The top level of U.LIST links all of these descriptions into one list. If a unit has no sonar or weapons, e.g., a convoy ship, or its sonar and weapons are irrelevant to a scenario, the IN deck constructs a unit description as shown in Figure 3-1 for U.LIST. The position and course data blocks are for time T.MIN, the beginning of the scenario. SET.PI adds another pair of data blocks so that all decks have position and course data for T-D.T and T available during their processing. The unit description is then as shown in Figure 3-2. If a unit has a sonar and weapons, the IN deck constructs the description shown in Figure 3-3. This list has provision for sonar set status and weapon data.

E. FLOW OF CONTROL

The EX deck is the executive control program (see flowchart in Figure 3-4). It calls IN to read the input data for a scenario and set up U.LIST descriptions for the units involved. Time is set to T.MIN and the initialization entries in each deck are called. This completes the processing necessary to begin the action.

The CE.NET call begins the program loop which is executed for each time-step during the course of the action. This call causes the CE deck to process the messages in CI.NET. CO.PRO begins a decision-action loop which processes all the units currently active (see the CO deck description in Appendix B). T is then advanced to T+D.T and compared to T.MAX. If the action is over, the PP deck is called to perform the post-processing analysis of the action. If the action is not over, the PI deck updates all position and course data blocks in U.LIST and control returns to the CE.NET call to continue the action.

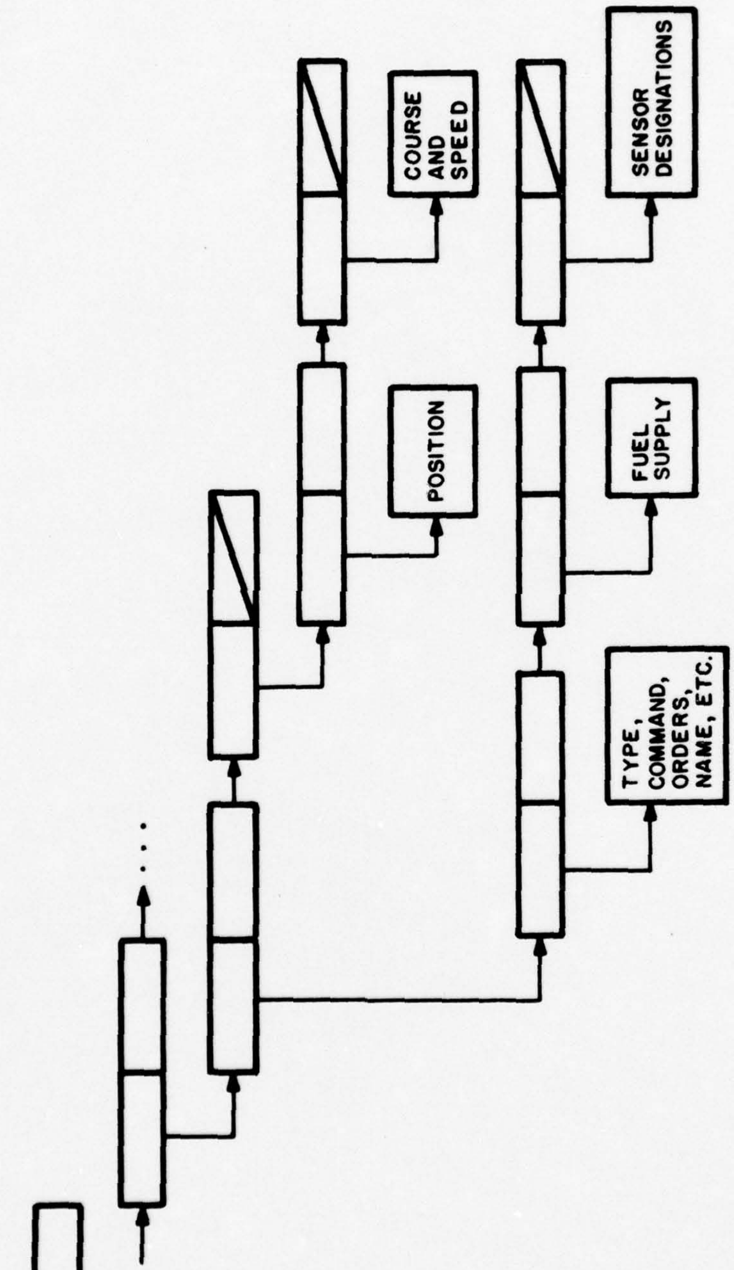


FIGURE 3-1. UNIT DESCRIPTION (WITH NO SONAR OR WEAPONS, BEFORE PROCESSING)

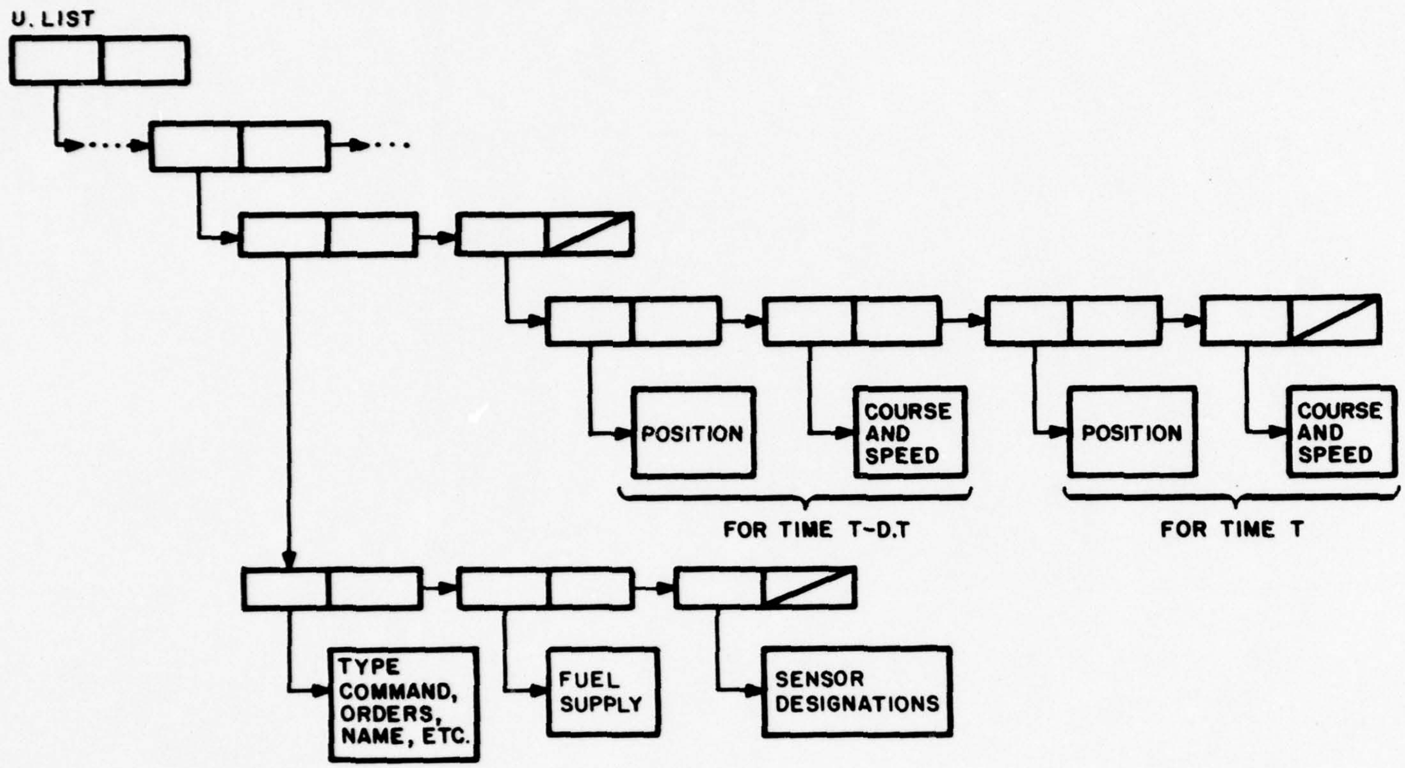


FIGURE 3-2. UNIT DESCRIPTION (WITH NO SONAR OR WEAPONS, DURING PROCESSING)

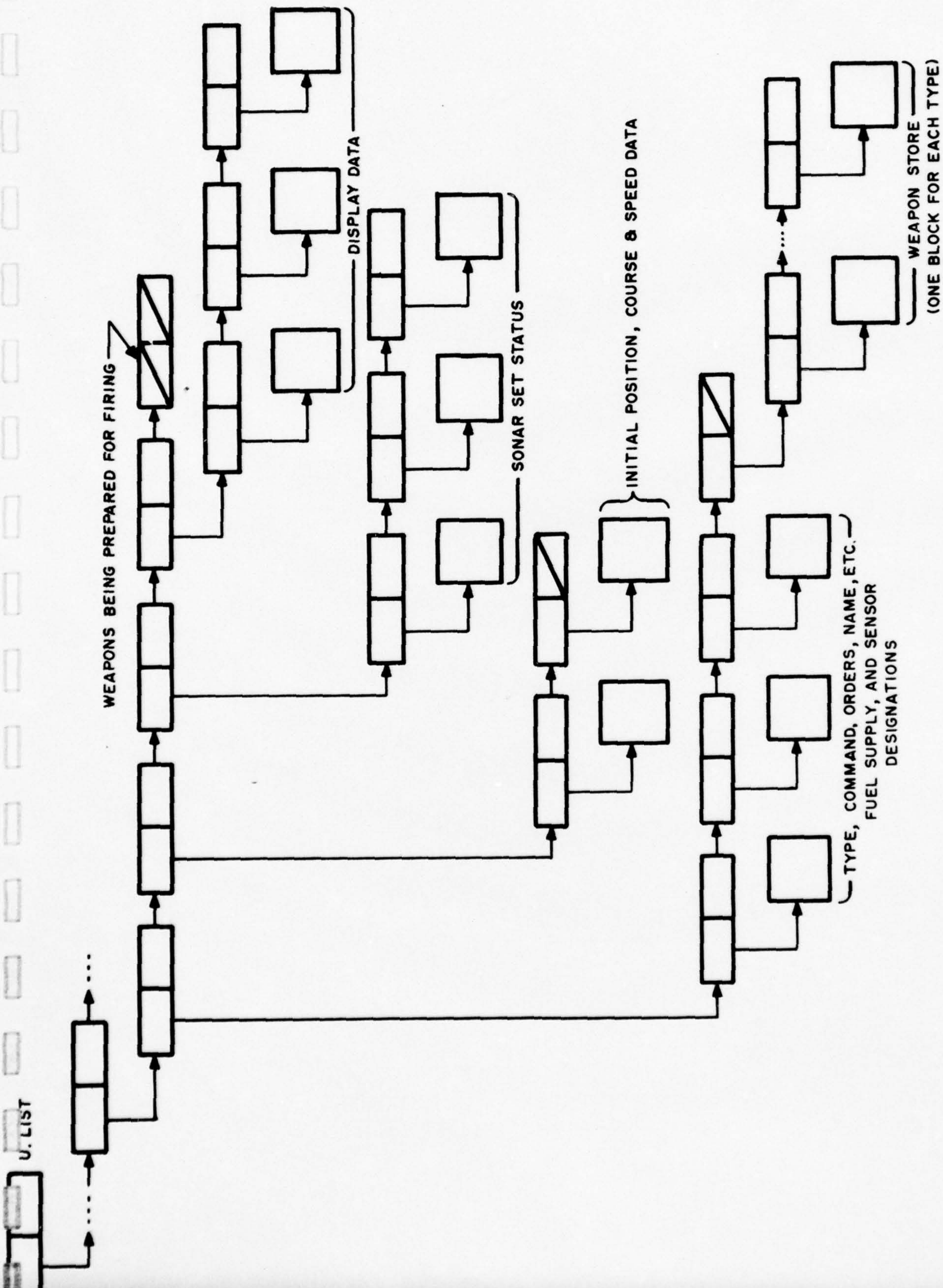


FIGURE 3-3. UNIT DESCRIPTION (WITH SONAR AND WEAPONS, BEFORE PROCESSING)

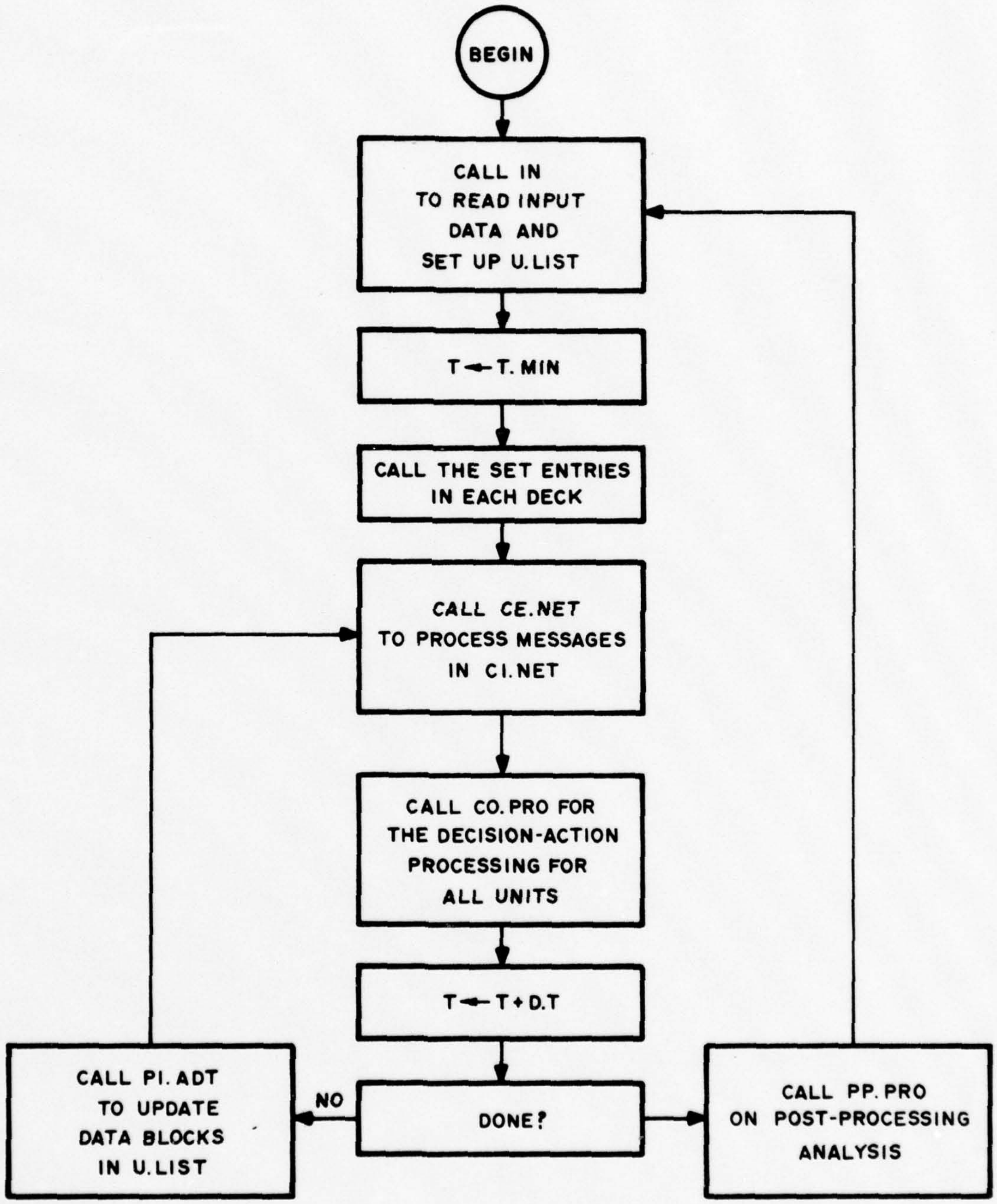


FIGURE 3-4. "EX" DECK FLOW CHART

APPENDIX A

TACTICAL CONTROL LANGUAGE

The current dictionary for the MEP tactical control language (TCL) is given in this appendix. The phrases in TCL were abstracted from an ORE exercise of some complexity*. Each of these phrases is represented by an abbreviation of at most 4 characters to facilitate the processing of TCL statements by the IN deck. The syntax of TCL is best shown by examples. Assuming that a submarine CO would base an action on the fact that his passive sonar was picking up echo ranging pings off the bow, the TCL statement for the information specification would be: "ERP-BOW". The hyphen between the two TCL abbreviations is a connective. For this specification to be satisfied, the sonar must not only be picking up echo-ranging pings (ERP), but they must also be off the bow (BOW). This specification could be made more precise if desired by adding other terms from the TCL dictionary which are appropriate, e.g., "ERP-LSC-BOW", "ERP-LSC-BOW-RC", etc. A comma is used to separate two specifications for the same source of information, e.g., "ERP-PBM,ERP-SBM" specifies that echo-ranging pings must be picked up off both the port beam (PBM) and the starboard beam (SBM). Blanks are used to separate specifications for different sources, e.g., "ERP-BOW DD-STN" specifies that the sonar must be picking up echo-ranging pings off the bow and a destroyer must be sighted off the stern for this information specification to be satisfied.

The following dictionary gives the TCL abbreviations used on input data cards, the TCL octal code used internally, and the meaning of each phrase currently in this language.

*Nagelhout, Savage, and Kistler, "Submarine Attacks: Procedures and Constraints in Attacks on Surface Ships (U)", SECRET, NAVWEPS Report No. 8526, NOTS TP-3592

TCL Dictionary

ASPR	0402	Assist prosecution
ATRN	3001	Attack turn
ATTK	0202	Attack phase
ATV	1101	Active sonar mode
BCL	1461	Bearing clear
BFL	1462	Bearing foul
BM	0601	Off the beam, either PBM or SBM
BOW	0602	Off the bow, RB -45 to +45
CLSN	3013	Collision course
DC	5011	Depth charge
DD	1411	Destroyer
DPDN	1213	Doppler down
DPUP	1211	Doppler up
EQ	1001	Equal
ERP	1221	Echo-ranging pings
ETRN	3002	Evasive turn
EVDE	0203	Evade phase
EXPN	5000	Have all been expended
FD	1441	Flaming datum
FIX	1402	Fixed object
FLT	1403	Floating object
FTC	5021	False target cannister
GE	1002	Greater than or equal
GT	1003	Greater than
HEAD	3014	Head directly at (tail chase)
HH	5012	Hedgehog
HIT	1442	Hit scored by a weapon
HMT	5001	Homing torpedo
HOLD	7077	Hold
HSS	1722	High-speed screws
HV	1412	Heavy (convoy) ship
HVS	1223	Heavy screws

INT	1241	Intensity
INTP	3021	Interpose
LE	1004	Less than or equal
LEAD	3012	Rough lead course
LSC	1231	Long scale
LSSC	1202	Lost sonar contact
LT	1005	Less than
MBC	0411	Maintain base course
MRB	0632	Magnitude of RB
MRR	0623	Magnitude of RR
MTA	0642	Magnitude of TA
MTBR	0653	Magnitude of TBR
NE	1006	Not equal
NODP	1212	No doppler
NONS	0421	Non-submarine contact
NOPS	1220	Nothing on passive sonar
NOSC	1200	No sonar contact
NOVR	1400	No visual report
NWV	3031	Narrow weave
OFF	1100	Sonar set is off
OTC	2601	Tactical commander of the force
OUT	0431	Out of action
OWN	1401	Own ship
PBM	0603	Off the port beam, RB -135 to -45
PCRL	3011	Pursuit circle
PNTR	0201	Penetration phase
POSS	0422	Possible submarine contact
PRSC	0401	Prosecute
PRSS	0423	Probable submarine contact
PSCP	1451	Periscope feather
PSSS	0424	Positive submarine contact
PSV	1102	Passive sonar mode

R	0621	Horizontal range
RB	0631	Relative bearing
RC	0611	Range closing
RO	0613	Range opening
RR	0622	Range rate
RS	0612	Range steady
SBM	0604	Off the starboard beam, RB 45 to 135
SC	1201	Sonar contact
SCH1	4001	Sonar procedure, Search Doctrine 1
SCH2	4002	Sonar procedure, Search Doctrine 2
SCH3	4003	Sonar procedure, Search Doctrine 3
SOA	0412	Speed of advance
SRCH	0200	Search phase
SRT	5002	Straight running torpedo
SS	1421	Submarine
SSC	1232	Short scale
STM	0605	Off the stern, MRB 135 to 180
TA	0641	Target angle
TB	0651	True bearing
TBR	0652	True bearing rate or drift
TRCK	0204	Track phase
VP	1431	Landbased aircraft
WA	5013	Weapon A
WWV	3032	Wide weave
****	7000	Irrelevant

APPENDIX B

DECK DESCRIPTIONS

Deck: AS
Function: A/S Officer

Entry: AS.ATK
Processes: CO..AS, CE..AS
Produces: AS..CE, AS..FO, AS..PI

This deck simulates the activities of the A/S officer on a unit. For a unit which is not in the attack phase, this consists of a call to FO.STO to erase the list of weapons in preparation for this unit.

For a unit which is in the attack phase, the AS deck conns the attack. CE.ATK is called to get the latest report on the target and the pilot control list, CDR(CO..AS) is modified for a collision course. AS..PI is constructed and PI.ATK is called to advance own ship. If own ship is not the command ship, FO.STO is called and this completes processing of the unit by the AS deck.

If own ship is the command ship, the AS deck directs weapon preparation and firing. CAR(CO..AS) is a pointer to the list of weapons which are to be prepared. AS..FO is constructed from CO..AS, and FO.PRE is called to begin weapon preparation. If own ship has a target report on its own equipment, the AS deck attempts to fire.

The list of weapons in preparation, in the top level of the U·LIST, is searched. Each weapon data block in this list contains an earliest time to fire, ETTF, and a range to fire, RTF. For each weapon in preparation, the AS deck computes a time to fire based on range rate and target range from the last target report. If this time is later than ETTF, and within the next time interval, FO.PNL is called to fire the weapon. For this call, AS..FO indicates the weapon to be fired and the time to fire. Processing of the weapon list completes the AS deck's functions for the command ship.

Entry: AS.FOM
Processes: FO..AS
Produces: AS..CE

This entry is used by the FO deck to advise the A/S officer that the stock of a weapon has been exhausted. The AS deck sends an internal message to the CE via AS..CE.

Deck: CE
Function: CIC Evaluation Officer

Entry: CE.ASM
Processes: AS..CE

This entry in the CE deck takes an internal message from the AS deck and inserts it in I.LIST.

Entry: CE.ATK
Produces: CE..AS

This entry in the CE deck supplies the latest report on the target being attacked to the AS deck.

Entry: CE.COM
Processes: CO..CE

This entry in the CE deck takes a message in CO..CE which the CO has ordered transmitted to another unit and puts it in W.LIST. It determines the length of the message and inserts the transmission time required in the data block for the message. The priority (assigned by the CO) is used to set the maximum waiting time.

Entry: CE.NET
Processes: CI.NET

This entry in the CE deck processes the messages for inter-ship communication. A.LIST is erased and the transmission times of the messages in C.LIST are updated. Messages which have completed the required amount of time in C.LIST are inserted in A.LIST. When this processing has been completed, the open channels in C.LIST are filled with messages selected at random from W.List. Then the messages remaining in W.LIST are processed. If a message has been waiting an excessive length of time for transmission, it is erased.

Entry: CE.RPT
Processes: LO..CE, SO..CE
Produces: CE..CO

This entry in the CE deck supplies information to the CO on which he will base his tactical decisions. It is the task of this entry to evaluate the information from the sensors in LO..CE and SO..CE before passing it on to the CO deck via CE..CO. Before performing this evaluation, the CE takes the internal messages for own ship from I.LIST and puts them into the appropriate section of M.LIST. Messages in CI.NET are then sorted into two groups. The messages addressed to own ship are put into one list, and those addressed to other ships are put into another list to allow own ship to monitor them. This completes M.LIST processing. If own ship is not under the control of a section in the tactical decision table, this will conclude the CE.RPT processing for own ship. If the CO of own ship must make a decision, the CE calls the LO and SO decks to get LO..CE and SO..CE.

The CE deck evaluates the sonar reports in SO..CE under the control of a limited-entry decision table which is set up by the CLASSIFICATION PROCEDURES... section of the input data. For each report in SO..CE the conditions specified by the condition stub are evaluated. The columns of the mask and table matrices are then tested (from left to right) to determine which decision rule is applicable. The action stub entries of the applicable rule determine the action taken by the CE.

The CE deck evaluates the visual reports in LO..CE under the control of tables in the CE deck. A table is selected for the type of unit on which the lookout is stationed. The quality of each visual report is then compared to the appropriate entry in the table which has been selected. This entry gives the minimum quality for a report to be given to the CO.

Deck: CO
Function: Commanding Officer

Entry: CO.PRO
Processes: CE..CO
Produces: CO..AS, CO..CE, CO..PI. and CO..SU

This deck simulates the decision making by the commanding officer of a unit. It is a loop that makes a decision and initiates action over the units currently active in U.LIST. CAR(UNIT.I) is the list describing the particular unit being processed (called own ship below).

The processing for each unit begins with a CALL to CE.RPT to get the CE..CO list. This list contains the information on which the CO will make his decisions: messages (both internal messages to the CO from his own men and messages on CI.NET from other units), sonar reports, and visual reports. Before making a decision, the CO processes the internal messages and the high priority messages on CI.NET. Certain messages, e.g., orders from the OTC, may preclude any decision considerations by the CO at the moment.

If the CO's decision for the next time interval is to be based on doctrine, the tactical decision table is processed. IDC (in the description data block) locates the first line in own ship's section of the tactical decision table. The first item in each line of this table is the operational phase to which the line applies, e.g., SRCH, ATTK, etc. PHASE (in the description data block) has the current operational phase for own ship. This is matched with the first item in each line until a line is found that is applicable. If no such line is found, the CO maintains the status quo.

Each line in the tactical decision table is divided into an information segment and an action segment. If the line is applicable to the current operational phase of own ship, the information segment is scanned. If the information

specified by this segment is a subset of the information in the CE..CO, then this line is satisfied and the action segment is scanned to create CO..AS, CO..CE, CO..PI, and CO..SU which are the orders to the A/S officer, the CIC evaluation officer, the pilot, and the sonar supervisor.

The last item in the action segment of a line is the operational phase to be initiated. After this has been stored in PHASE the CO calls CE.COM (to send a message), PI.ADV (to advance the position of own ship, if own ship is not in the ATTK phase), AS.ATK (to conn the attack, if own ship is in the ATTK phase), and SU.DOC (to set sonar operating procedures). After these calls, own ship will have been advanced to the point along its track associated with time T+D.T . The information generated because of this motion will not have been computed at this point in the program because this cannot be done until all units have been advanced.

After these actions have been initiated, the list structure words and data blocks no longer needed are returned to LIST.. and DATA.. in GL. This completes the processing of a unit. IF U.LIST is exhausted, control returns to the EX deck. If not, control returns to the beginning of the decision-action loop and the next unit in U.LIST is processed.

Deck: FO
Function: Firing Officer

Entry: FO.PNL
Processes: AS..FO

This entry simulates the firing of a weapon by the unit's firing petty officer. AS..FO indicates the weapon to be fired and the time to fire. The FO deck deletes the weapon data block from the list of weapons in preparation in the top level of the U.LIST . Provision has been made for regarding the weapon which has just been fired as a new unit, and entering its description into the U.LIST as an addition to the lists of units currently active.

Entry: FO.PRE
Processes: AS..FO
Produces: FO..AS

This entry simulates the weapon preparation activities of the firing petty officer. AS..FO indicates the weapon to be readied. If the desired weapon is already being prepared, the firing officer's processing is complete. If preparation has not already been initiated, the firing officer checks the weapon store in the U.LIST description for own ship. If the stock of this weapon has been exhausted, the firing officer sends an internal message to the A/S officer via FO..AS, and the firing officer's processing is complete.

If neither of the above conditions exist, the firing officer reduces the stock of this weapon and constructs a weapon data block. This data block contains the weapon designation, firing range and an earliest time to fire. The firing range and weapon preparation time are obtained from tables internal to the FO deck. The weapon data block is inserted into the list of weapons in preparation, and this completes

processing of the unit by the FO deck.

Entry: FO.STO

This entry simulates the activities of the firing petty officer when an attack is called off. The list of weapons in preparation is erased and the weapon store is updated.

Deck: LO
Function: Lookout

Entry: LO.RPT
Produces: LO..CE

This deck simulates the action of a lookout and produces the visual reports given to the CE deck for evaluation. If own ship is below the depth at which a lookout can see other units, LO..CE is cleared and control returns to the CE deck.

If it is possible for the lookout to see other units, then height and time of day factors are found by interpolation in tables in the LO deck. The range the lookout can see is a product of these factors and the range of visibility (an input parameter).

After the range that the lookout can see has been found, each unit in U.LIST is processed (except for own ship) to determine if the unit is visible to the lookout. The range to each unit is divided by the range the lookout can see to obtain a normalized range which is used as an argument for interpolation purposes. A table is selected from those in the LO deck for the type of unit being sighted and the conditions which currently exist, e.g., whether the sun is up or not, whether the unit has darkened ship or not, etc. If it is a periscope or periscope feather which is being sighted, the sea state (an input parameter) is used to select a table. Interpolation in the table selected yields the "quality" of the sighting. If it is zero, no visual report is created for this unit. If it is not zero, a visual report is inserted in LO..CE for evaluation by the CE deck.

Deck: PI
Function: Pilot

Entry: PI.ADT

This entry in the PI deck updates the position and course data in U.LIST for all units currently active. The track of a unit is from P3 to P2 to P1. The PI.ADT entry deletes the current P3 data blocks for position, course, and speed data so that the current P2 blocks become the next P3 blocks because of their position in the list structure. Since the current P1 data blocks follow these blocks, they become the next P2 blocks. When this processing has been completed, there are no P1 data blocks. These will be supplied by the entries described below as each unit is advanced from P2 at time T to P1 at time T+D.T .

Entries: PI.ADV and PI.ATK
Process: CO..PI or AS..PI

Both of these entries in the PI deck advance the unit described by CAR(UNIT.I). PI.ADV assumes that CO..PI is the pilot control list, and PI.ATK assumes that AS..PI is the pilot control list. This list contains data blocks which specify the course, speed, and depth or altitude (if own ship is not a surface ship) maneuvers desired. If these maneuvers are the same as the current maneuver given in the P2 data blocks, then they are continued. If not, new maneuvers are initiated. After the maneuvers have been determined, the desired course heading, speed, and depth or altitude are computed. The change in course heading is limited to a value from a table in the PI deck. The limit depends on the type of unit being advanced. The desired horizontal speed and depth or altitude yield speeds and changes in speed which are also limited by tables in the PI deck. The unit is then advanced by constructing the PI data blocks in U.LIST which give the position,

course, and speed data for time T+D.T, and the fuel supply for the unit is reduced by the amount required for one step of D.T .

Deck: SO
Function: Sonar Operation

Entry: SO.RPT
Processes: SU..SO
Produces: SO..SU, SO..CE

This deck simulates the sonar set and operator on a unit. When processing of a unit is complete, SO..CE contains all the sonar reports which have occurred in the current time step.

There are five different types of sonar reports which could be entered in the SO..CE list. For an active mode of operation, the sonar reports would include ping and echo reports. For a passive mode, they would include noise and ping glimpse reports. The first report in the SO..CE list is always a status report which indicates the sonar mode of operation. Additional status reports in SO..CE would indicate a change in sonar operation mode. Echo, noise and ping glimpse reports include target information, such as range and bearing, and an intensity index. This intensity index is computed by linear interpolation in tables internal to the SO deck. There are different sets of range vs. intensity index tables for each report type, sonar set, and target depth (above or below the layer).

Processing of own ship begins by putting a pointer to own ship in SU..SO and calling SU.PRC to get the sonar control list. This list contains all console configurations required by a particular procedure for the current time interval. Ping and mode change entries in this list are used to construct the ping and status reports for the SO..CE list. Processing of an entry in the sonar control list depends on the sonar mode.

Active sonar processing is essentially a loop over the U.LIST to find possible targets. Ping glimpse and echo geometry are computed for each possible target. If an echo has reached the sonar set within this time step, an echo

report is constructed and put into the SO..CE list.

Passive sonar processing is essentially a loop over the U.LIST to find possible noise and echo ranging ping sources. If a unit is a possible noise source, a noise report is constructed and put into the SO..CE list. If a unit is a possible echo-ranging ping source, a pointer to the unit is put in SO..SU and SU.PRC is called to get the sonar control list. For each ping entry in this list, ping glimpse geometry is computed. If a ping glimpse has occurred while own ship is in the passive mode, a ping glimpse report is constructed and put in the SO..CE list.

When all the operations in own ship's sonar control list have been performed, the last entry in the sonar control list is entered into the sonar status region of the U.LIST . This status data represents the final status of the sonar set for this time step.

Deck: SU
Function: Sonar Supervisor

Entry: SU.CTL

This entry updates the sonar status region in the U.LIST . During a time step the SO deck inserts sonar status data corresponding to time T into the U.LIST . At the end of a time step, the sonar status region contains data for T-D.T and T. The SU deck deletes the data for time T-D.T . When T is advanced to the next time step, the data in the sonar status region refers to T-D.T .

Entry: SU.DOC
Processes: CO..SU

This entry simulates the implementation of the CO's decision to initiate a sonar procedure. CO..SU indicates the procedure to be initiated. If the desired procedure is already in effect, the processing of the unit by the SU deck is complete. Otherwise, the sonar status data in the U.LIST which corresponds to time T is modified by the supervisor to cause the new procedure to go into effect at the beginning of the next time step.

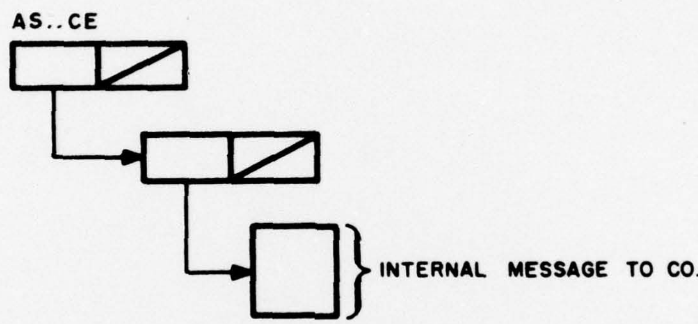
Entry: SU.PRC
Processes: SO..SU
Produces: SU..SO

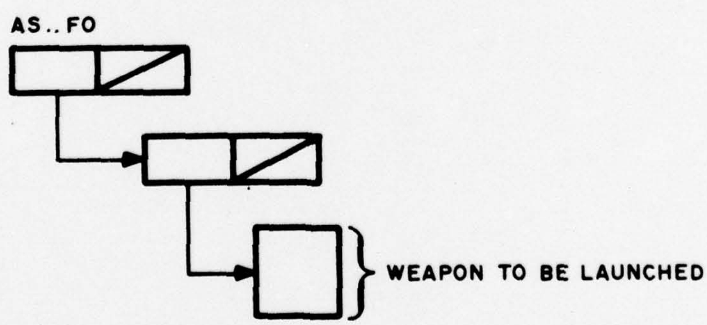
This entry simulates the functions of the sonar supervisor for the unit specified in SO..SU . The task of this entry is to produce the sonar control lists. The sonar control list contains the procedural data necessary for sonar set operation. Procedural data is obtained from tables internal to the SU deck. Sonar procedures are effective for at least one time interval. Sonar operating modes, pulse spacing, and other operating

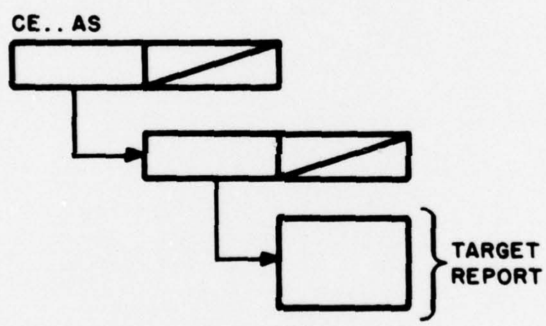
parameters are functions of the procedure definition and not the basic time step. Thus, provision has been made for a variety of operating techniques within a single procedure specification.

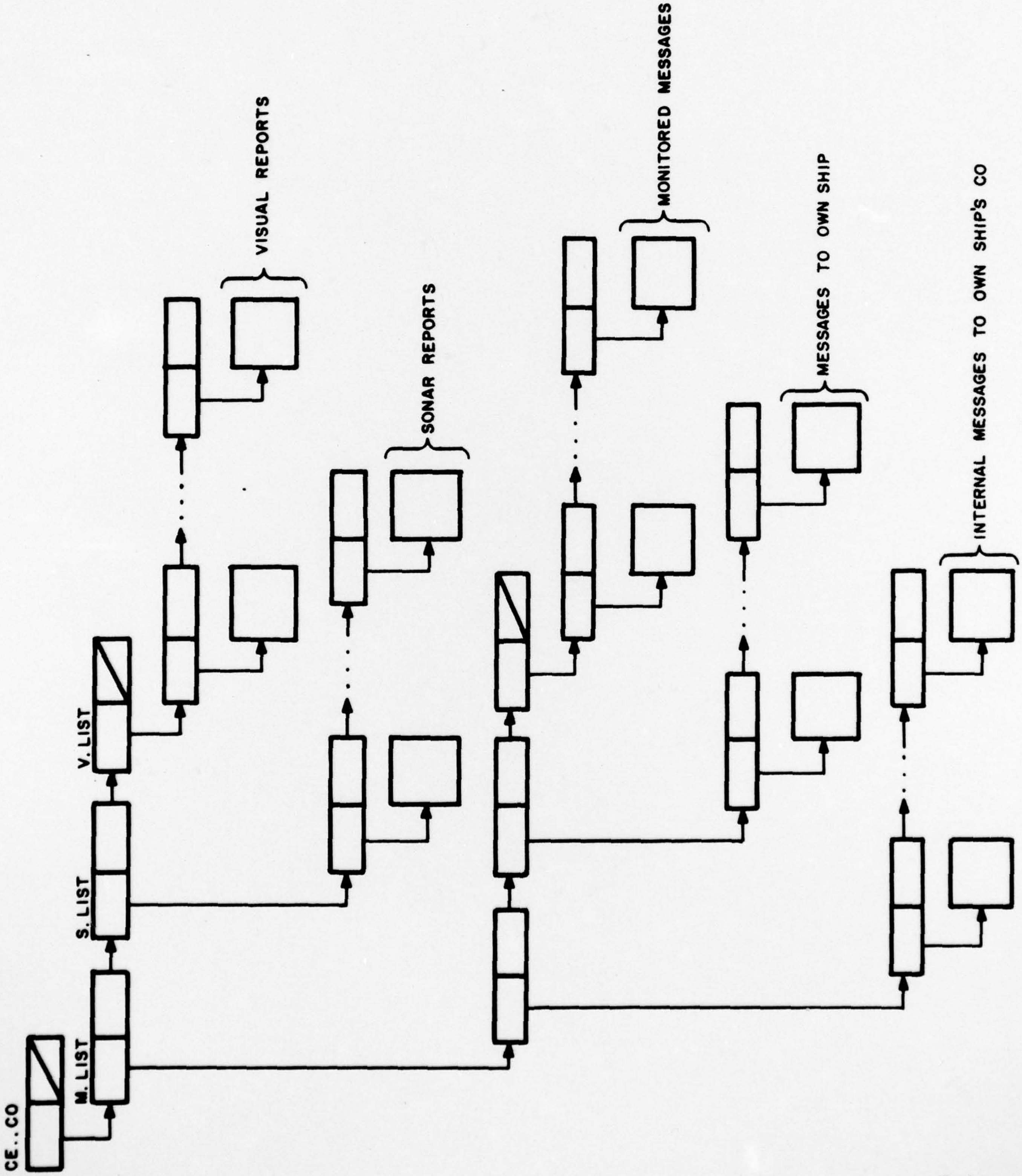
Appendix C

List Diagrams

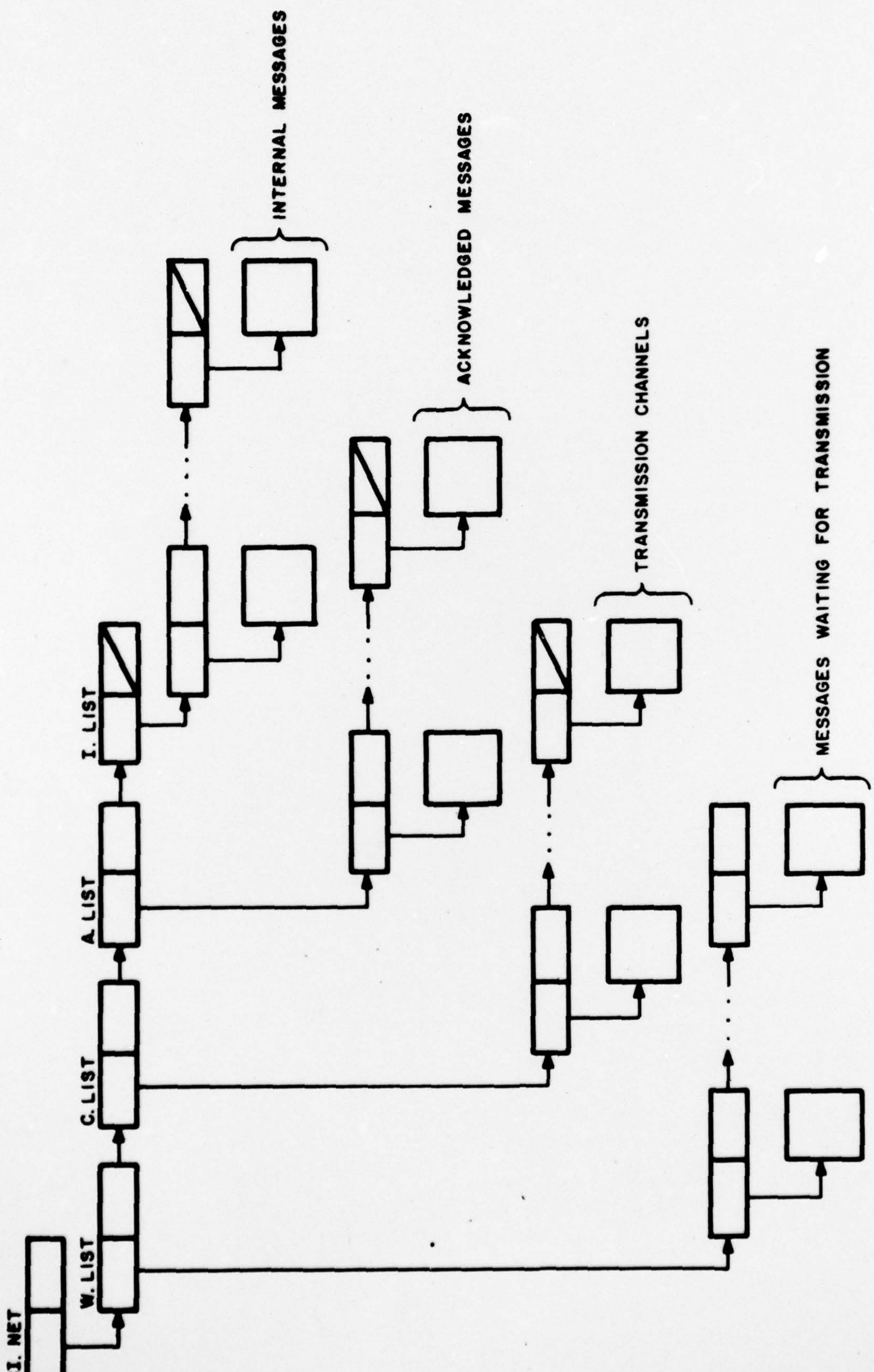

AS..CE
INTERNAL MESSAGE TO CO.

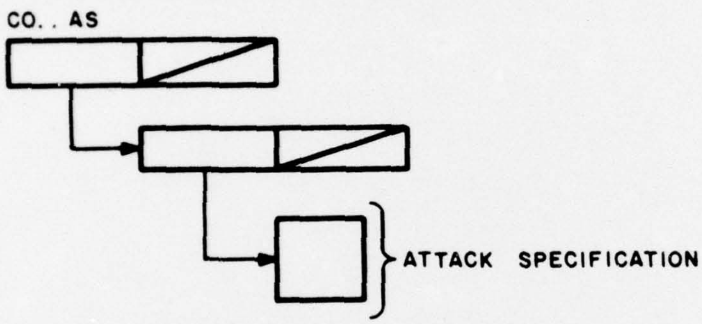

AS..FO
WEAPON TO BE LAUNCHED

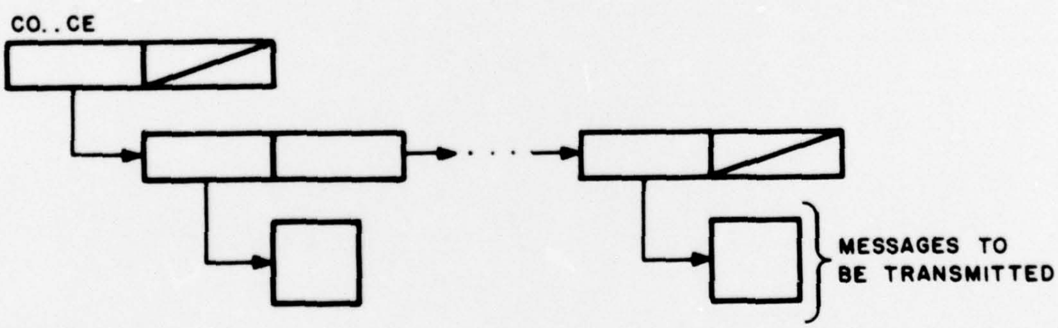

CE.. AS
TARGET
REPORT

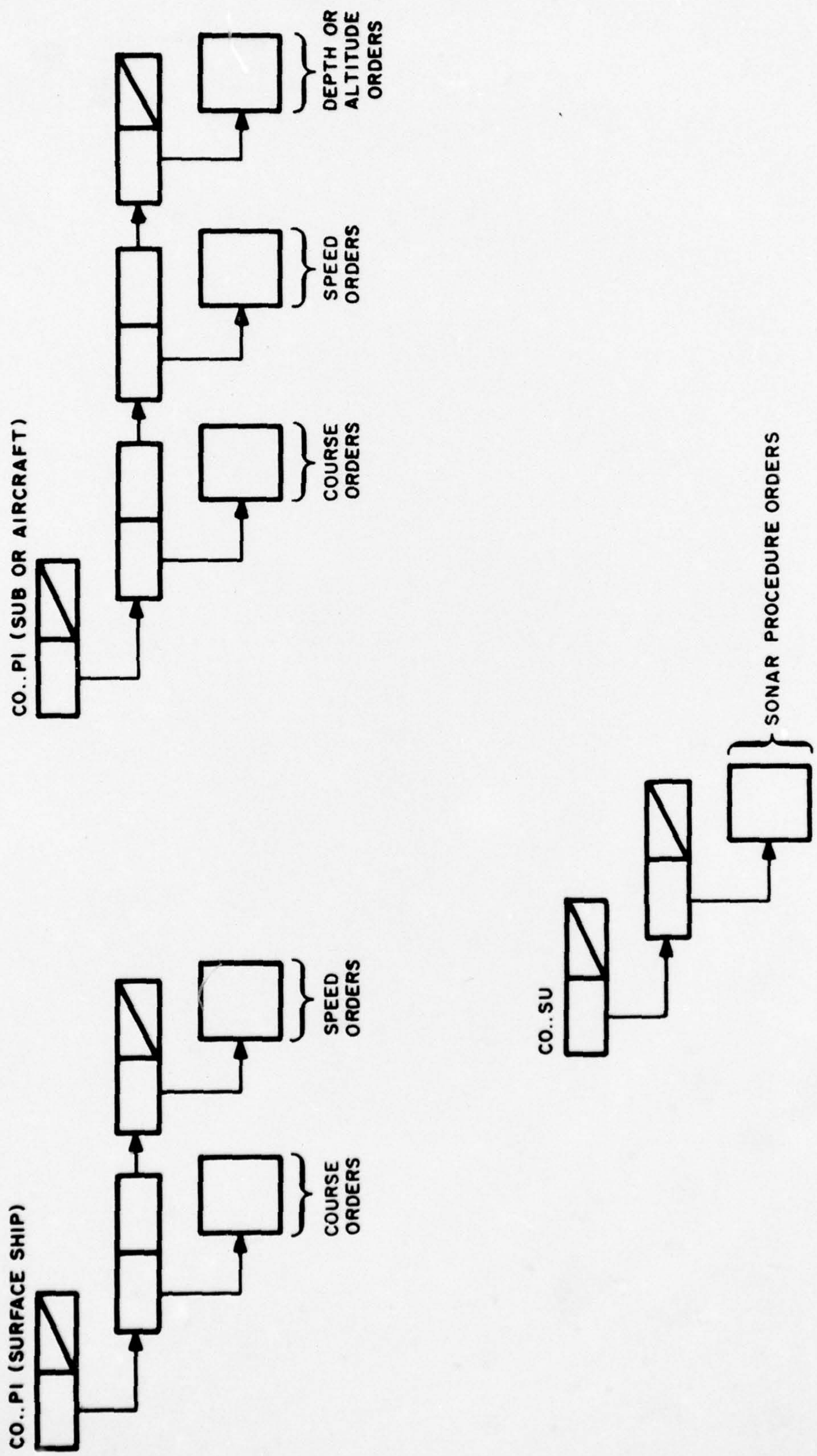


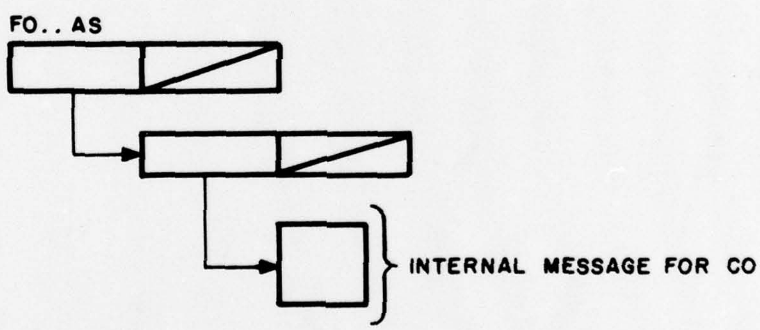
CE..CO
M. LIST
S. LIST
V. LIST
VISUAL REPORTS
SONAR REPORTS
MONITORED MESSAGES
MESSAGES TO OWN SHIP
INTERNAL MESSAGES TO OWN SHIP'S CO

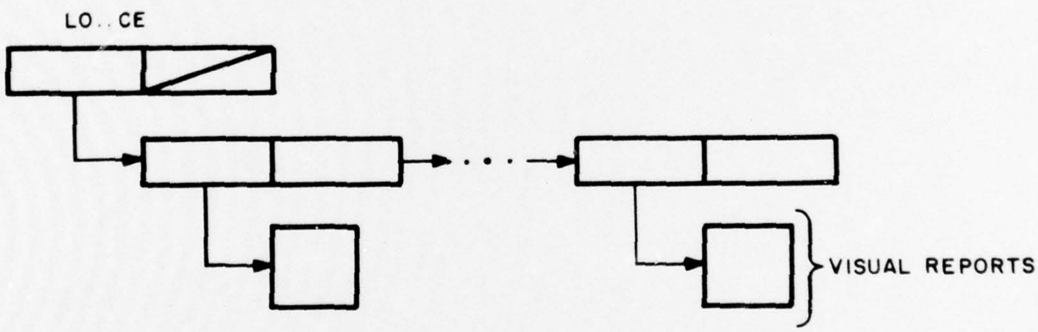

CI. NET
W. LIST
C. LIST
A. LIST
I. LIST
INTERNAL MESSAGES
ACKNOWLEDGED MESSAGES
TRANSMISSION CHANNELS
MESSAGES WAITING FOR TRANSMISSION

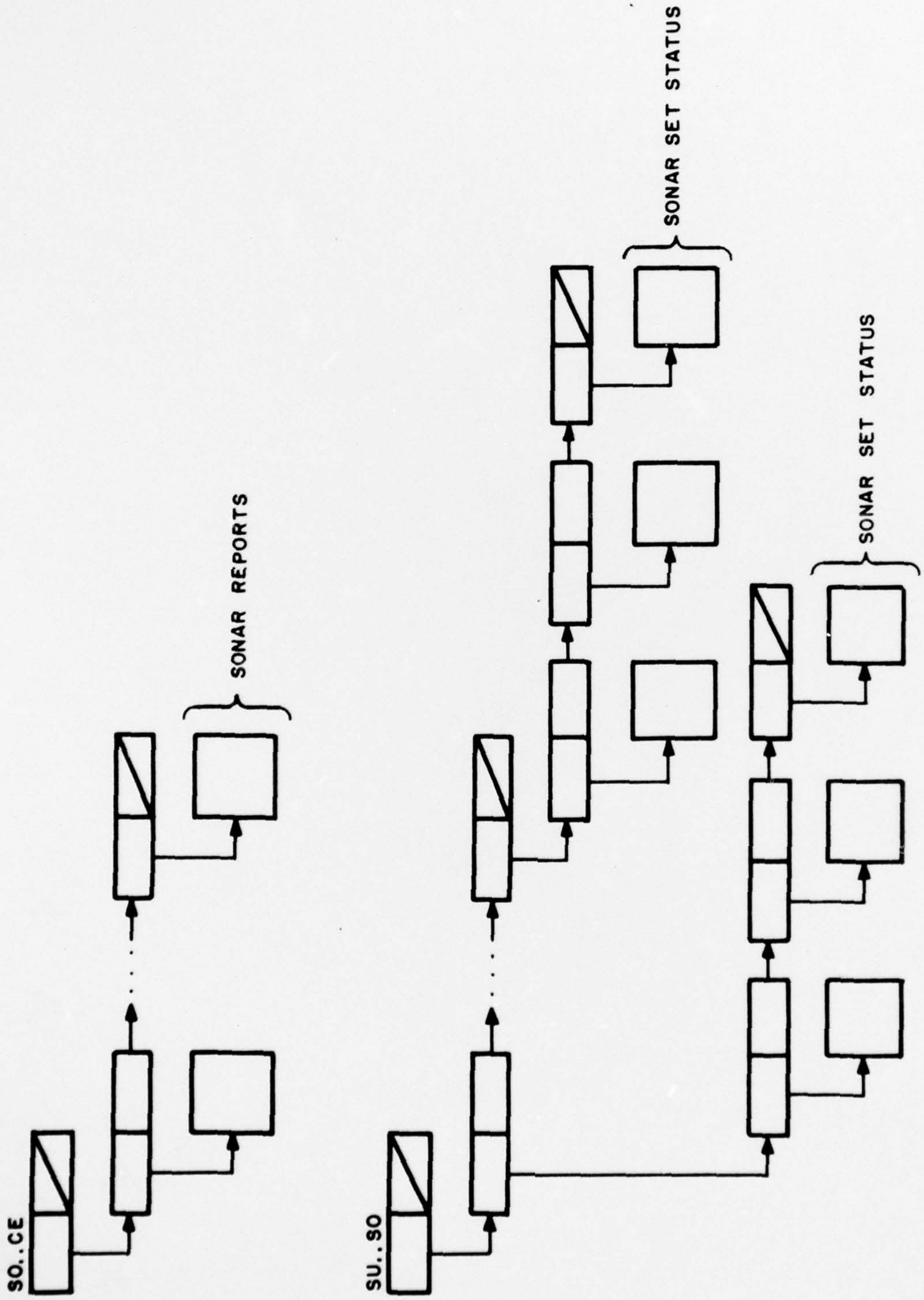

CO..AS
ATTACK SPECIFICATION


CO..CE
MESSAGES TO
BE TRANSMITTED


CO..PI (SUB OR AIRCRAFT)
COURSE ORDERS
SPEED ORDERS
DEPTH OR ALTITUDE ORDERS
CO..PI (SURFACE SHIP)
COURSE ORDERS
SPEED ORDERS
CO..SU
SONAR PROCEDURE ORDERS


FO..AS
INTERNAL MESSAGE FOR CO


LO..CE
VISUAL REPORTS


SO..CE
SONAR REPORTS
SU..SO
SONAR SET STATUS
SONAR SET STATUS